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DESIGN AND SIMULATION OF SPOT WELDING PROCESS

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ABSTRACT

The presented work confirmed that the use of resistance spot welding process in industry can be considered as one of the widely processes applied for sheet joining purposes. Finite element modelling technique is an efficient tool which can be effectively and efficiently applied to describe the welding process. The effect of electrode geometry on current distribution has been investigated. A model of thermo-mechanical- electrical coupling with two dimensional axisymmetric is created to explain the process of weld. The modelling is completed to run the electrode lifetime and present distribution in the electrode face. Both thermal-electrical and mechanical evaluation is made to create version. During simulation, background of temperature and procedure distributions had been called. Development of weld nugget through procedure and impact of process parameters on nugget formation have been researched. Good agreement of uniform current distribution is extracted from the computational investigation, which allows including the benefits of design and simulation of processing weld related to production performance and cost.

KEYWORDS: Resistance Weld, Spot Weld, Thermo-Mechanical-Electrical, Electrode Simulation & Temperature Distribution

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Original Article

1. INTRODUCTION

In 1880, Elihu Thomson found the resistance spot welding joints by massaging resistance heating of components (Al, 2003), [1]. Resistance spot welding is the joining technology in the sector [1]. This is due to its low costs and high efficiency. Resistance spot welding is classified as one of the types of welding, which is characterized by joining two or more discrete areas of metal parts in the form of joining spots at the sheet interface. Unlike arc welding, the joining is confirmed by use of electrical resistance rather than electric arc. Welding parameters like Current, Time and Force need to be controlled efficiently, so as to produce great weld quality.

The heat is generated across two or more sheets, due to resistance to current flow through the metal sheets. After heat generation, the temperature starts to increase between intimate surfaces to reach a value of plastic point of sheet metal, where the fusion can occur and the nugget region is formed. Following it, the current is switched off to permit the sheets to combine to produce a nugget when the temperature declines. Figure 1 shows the structure of this welding procedure in businesses as well as the car industries.

Today, resistance spot welding process has become more reliable and applicable technique entered effectively in many fields such as automotive industry and aerospace, in addition to other products including appliances, furniture and small scale circuit elements.

2. LITERATURE REVIEW

Some work has already been carried out on analysis and simulation of welding process through modelling of the weld region using numerical modeling, to create an axisymmetric heat conduction model in order to investigate 3D modelling of the growing nugget area by setting different currents. (S. H. Lin et. al, 2003) and (Y. J. Chao, 2003) and (J. A. Khan. et. al, 1999) and (C. L Tsai. et. al, 1984) Ref no [1-4]. Part of studies involve finite element model using ABAQUS software to investigate an axisymmetric, employing coupled thermal-electrical-mechanical analysis (H. A Nied, 1984) and (Cheikh, Guendouze, 1995) and (H. P. C. Daniels, 1965) Ref no [5-7]. Also, a study of investigating welding parameter on spot weld is contributed through using ANSIS code to explain a 2D axisymmetric weld model. Additionally, more complex FEM versions, which contemplated temperature dependent material properties, contact status, stage altering and combined field effects to the simulation of resistance spot welding (RSW) have been improved (C. L Tsai, et. al, 1991) and (J. A. Khan, 2000) and (De, and M. P. Theddeus, 2002) and (E. Klm, and T. W. Eagar, 1988) Ref no [12-15].

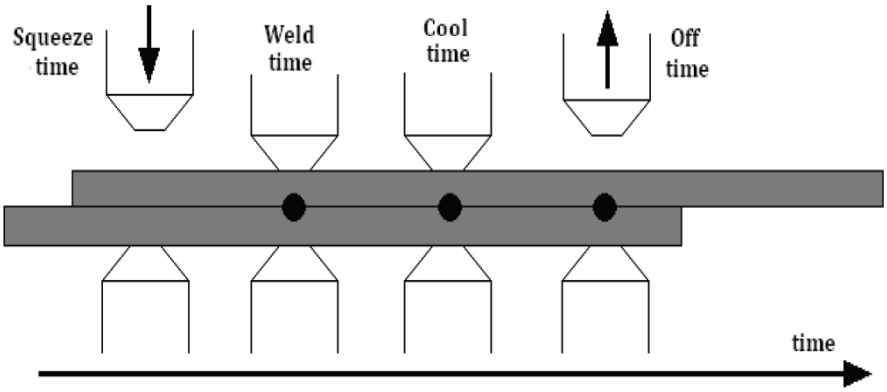


Figure 1: Schematic of Spot Welding Process.

3. THEORETICAL PART

The governing equation in two dimensional cylindrical coordinate for conduction system, with internal heat production could be considered: (S. P. Timoshenko, and J. N. Goodier, 1970) Ref no more [16]:

$$\frac{1}{r}\frac{\partial}{\partial r}(rK\frac{\partial T}{\partial r})+\frac{1}{r}\frac{\partial}{\partial z}(rK\frac{\partial T}{\partial r})+\dot{Q}=\rho c\frac{\partial T}{\partial t}$$

Where, r and z are radial and axial coordinates and ρ, c, and K are density, specific heat, and thermal conductivity of this substance. The material properties are assumed to be temperature dependant. The expression 'Q' describes the speed of the heat production, per unit volume. This term accounts because of bulk resistivity from the system for the Joule heating. It's been supposed that the border at the edge, in contact with the water, is kept at temperatures. The boundary conditions could be said as follows:

$$T = T_{S1}$$

Tst is fever of the interior surface of electrode. About the surface of Electrode, the boundary state *is:*

$$q = -K\frac{\partial T}{\partial n} = \alpha(T - T_o)$$

Where q, *O T*, and α would be the heat production per unit volume, temperature of the surrounding atmosphere, and heat transport continuous. ∂/∂n is your gradient across the outward normal direction of the border.

4. RESISTANCE SPOT WELDING PARAMETERS

The resistance spot welding process can be clarified by a number of parameters such as welding present, clamping other parameters in addition to welding and pressure period. In order to achieve good quality weld, there is a need for effective and proper control between parameters. There are four stages in the spot welding process; squeeze cycle, weld cycle, holding and off cycle. Whereas, employing of force must confirm bonding through period, the electrode is attracted to touch to permit for weld.

Ultimately, sheets have been formed that may lead to make a nugget, the point can be exceeded by the temperatures, while the inadequate may lead to expulsion. Proper control can be obtained by modelling of the welding process, using the ANSYS software.

5. ESTABLISHMENT OF THE RESISTANCE SPOT WELDING MODEL

Controlling of the spot welding process is not easy due to the difficulty between welding parameters. The complexity of spot welding process is found due to involvement of several factors like for example mechanical, thermal, electrical and metallurgical factors. Therefore, it depends on developed model of weld process with axisymmetric 2-dimensional, which is the key to overcome this complexity. Building up a model by using ANSYS code is more reliable to save more time and to obtain more accurate results. Several finite element models of weld have been easily developed to arrange an axisymmetric model as shown in Figure 1, the electrode shape is designed and material model is created; only one quadrant of the model was constructed.

As revealed in Figure 2, the simulation models are performed through supplying two kinds of evaluation; a structural investigation and a thermal-electric investigation. The former analysis is utilized to test the compressive Von-Mises pressures, developed through the squeeze time. And, the next evaluation (thermal-electric investigation) is modelled in the nugget region and reveals the rise of the joint throughout the procedure time, through signal of temperature distribution throughout the interval.

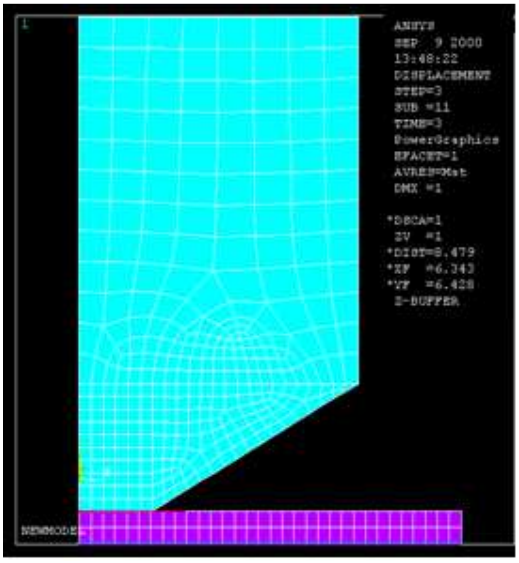


Figure 2: 2D Finite Element Model.

6. SELECTING OF MATERIAL PROPERTIES AND BOUNDARY CONDITIONS

Figure 3 shows the schematic illustration of the process. Weld's process starts with the squeeze cycle, where the effect of pressure is imparted upon the electrode into the area. At squeezing stage, Von Mises stresses, deformation and variation of contact area can be analyzed. Both electrical and thermal fields are solved simultaneously, analysis of electro-thermal is used as an input to the thermal mechanical, which will be passed to the electrical thermal as an input.

Applying of electrical energy leads to generate thermal effect, which is computed in electrical-thermal analysis. Many processes were repeated at each time increment, until the completion of weld cycle. Within this version, the electrode has been taken as aluminum, and steel sheets AISI1008 were utilized for the work pieces from the welding procedure. The properties like Young's Modulus thermal conductivity, substance resistivity, specific heat and enthalpy were chosen for simulation (ASM Hand Book, 1990) Ref no [8]. Air heat, cooling water temperature, electrode voltage and force were entered into the simulation because of the boundary condition of those models (ASM H Novel, 1998) Ref no more [9]. Figure 4 displays the boundary conditions applied to this version. Both characteristics (shown in Table 1) of thermal and electrical contact resistance were modelled analytically, as described before in the previous section.

Table 1: Thermal and Electrical Characteristics of Analysis

Sheet thickness (mm)	0.8
Electrode face diameter (mm)	5
Ambient air temperature (°C)	25
Temperature of water inside the electrodes (°C)	25
Convection coefficient of ambient air (W/m2. °C)	21
Convection coefficient of water (W/m2. °C)	300

The properties of materials were considered nonlinear, temperature dependent, while welding parameters used in analysis were: 2.5 kN for electrode force, 50 Hz for welding current, 11 cycles (0.22s) for welding time and 5 cycle (0.1s) set for holding time. In Evaluation, both Electrical and Thermal contact conductivity were found temperature-dependent in the intimate surfaces.

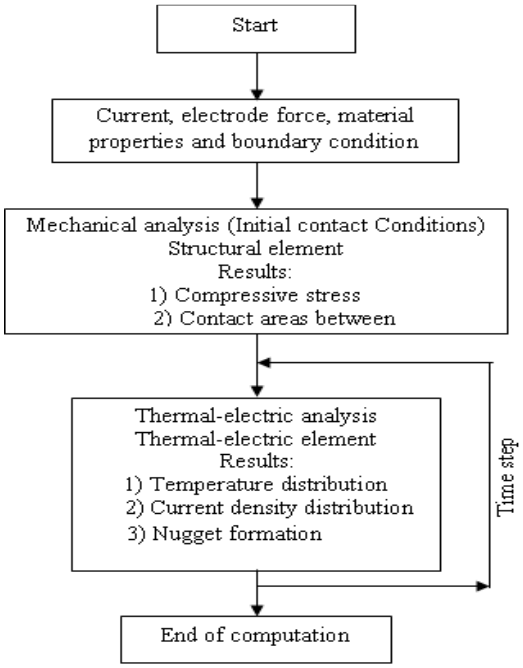


Figure 3: Schematic Illustration of Computational Analysis.

To simulate the evaluation, Airplane 77 has been utilized. This component has the capacity of thermal-electrical, electric and thermal analysis. Using Plane 40, this component had been replaced in the analysis. You will find three contact places from the model. Two contact places represented the one, and also the interface represented that interface. The contact pair components (Targe170 and Conta173) were used to mimic the contact locations.

7. RESULTS AND DISCCUSIONS

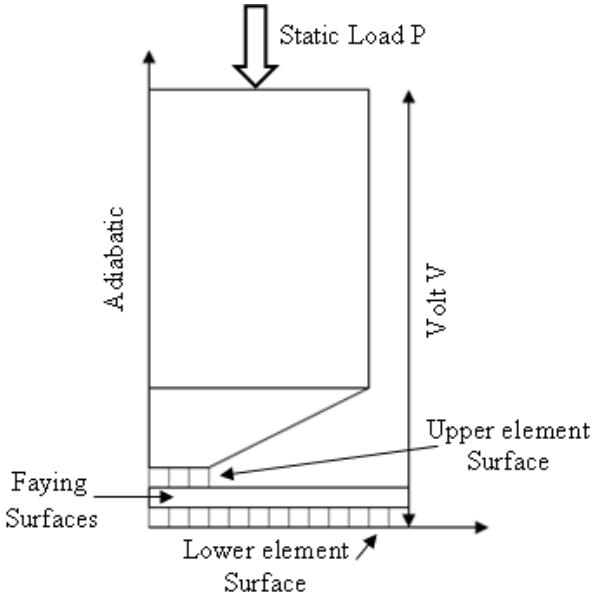


Figure 4: Boundary Conditions.

In simulation model of spot welding process, the static load was specified to apply at the upper part, as shown in Figure 4 Stress distribution, at the intimate area between electrode tip and sheet, and between sheet to sheet interfaces was carried out. Because of axisymmetric model, radial displacement is restricted across the centreline. Figure 5 displays the result. In this figure, the distribution of compressive pressure shows clear variant beginning from the centerline to the edge of the electrode, as well as the sheets metals.

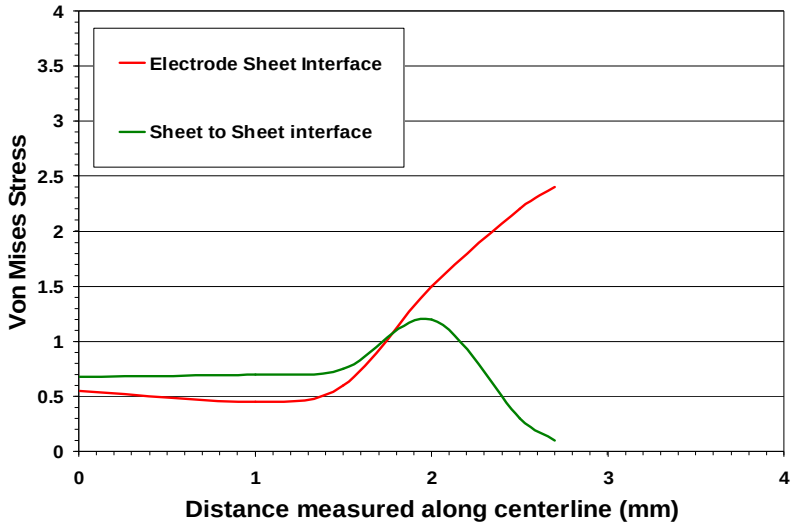


Figure 5: Variation of Stresses along (a) the Electrode Sheet Interface (b) the Sheet to Sheet Interface.

The results of modelling indicate that, the value of stress distribution at the electrode to sheet was even higher than the sheet to sheet intimate surfaces. Maximum stress was recorded at the edge of the electrode with a value equal to 2.4 N/ mm^2, while 1.2 N/ mm^2 is recorded as the maximum value of stress between sheets. Good agreement of the results is compared with those results presented by Nied's (H. A Nied, 1984) Ref no [5], even though his work was carried out on aluminium sheets.

8. THERMAL-ELECTRIC ANALYSIS

Within this work, the place welding version quantified the effect of electrode on thermal-electrical conduction and pointed out that the warmth made by electrode is comparatively tiny. In structural analysis, the used component is substituted by an equal quadrilateral thermal-electric good component. A voltage is applied across the top region of the electrode, then imparted to the sheet, which it contributes to v transient evaluation of this resistance spot weld. The cause of picking a voltage is a result of the equivalence into the welding current. Finite element model of weld is analyzed effectively, after requiring of thermal properties for the selected metals (copper and steel).

The model revealed that nugget initiated at a distance in the Centre in a ring shape, enlarged outward and inward throughout the welding cycles. Based on temperature distribution predicted in finite model, the increase in nugget area is fixed as a function of welding current (Nijaguna, B. T, 2005) and (D. Richard, M, et. al, 2003) [10, 11]. The observation of modelling indicates that the thermo-mechanical interactions of the welding process is affected by voltage, electrode pressure and holding time. Further, effect on the change of nugget geometry. Figure 6 shows the predicted isothermals and nugget shape.

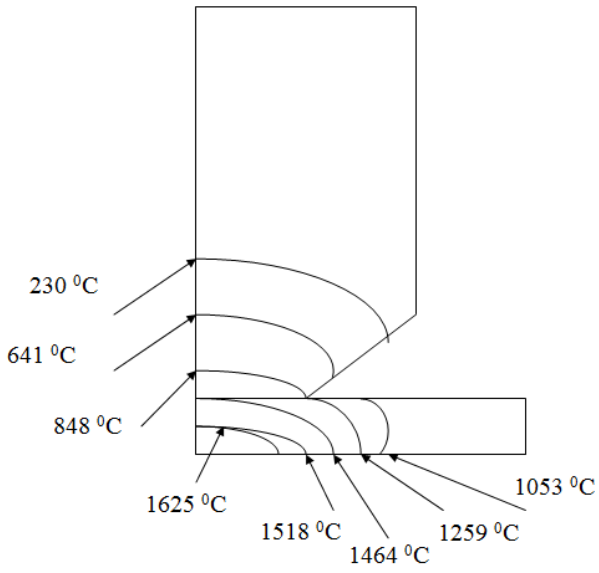
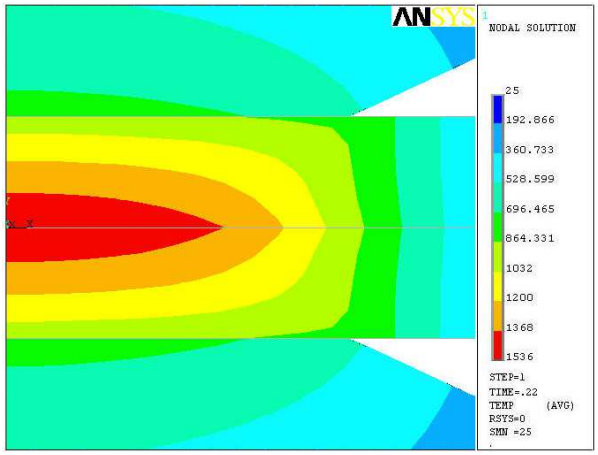


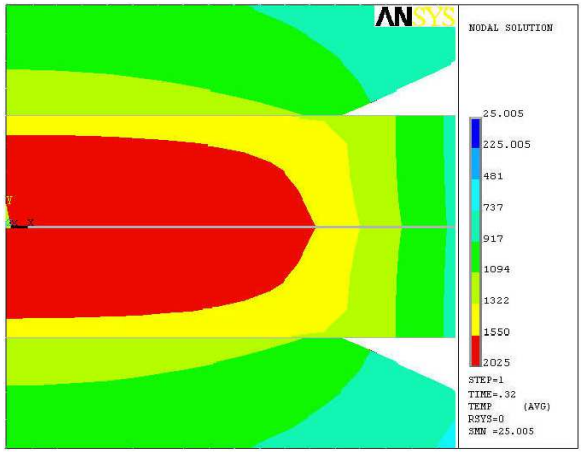
Figure 6: Isothermal and Nugget Shape.

9. PREDICTION OF NUGGET SIZE AT DIFFERENT WELDING STAGES

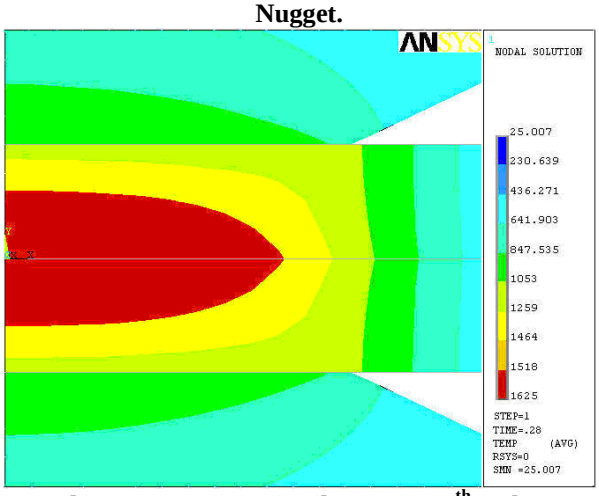
Among the parameters in resistance spot welding is weld nugget. Figure 7 displays temperature distributions of weld. The temperature was present throughout the procedure, at the middle of touch surface. Temperature of touch surface was higher than that of interface. In the cycle, the temperature was attained. The temperature distributions now have been displayed in Figure 7(a) that is Nugget's form. Temperature in this period was 2025 °C.



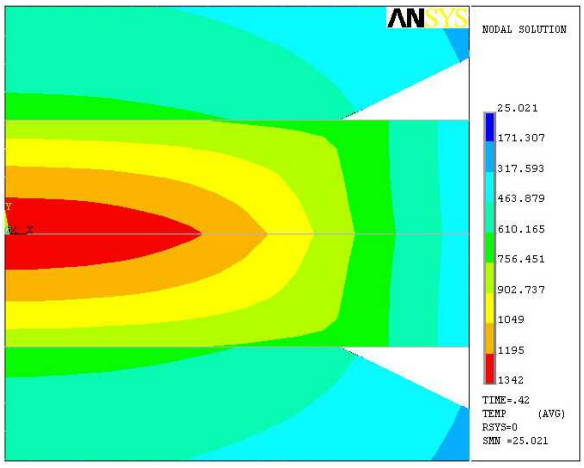
(a) Temperature Distribution at Starting form of Nugget.



(c) Temperature Distribution at Switched off the Current.



(b) Temperature Distribution at 11th cycle.



(d) Temperature Distribution at the end of Analysis.

Figure 7: Temperature Distribution of Welding Process at different Times.

The Highest temperature of nugget Centre was 2025 °C at the end of Final Present cycle, as shown in Figure 7(c), but the Temperatures Immediately Begin to decrease after Shifting the current to Achieve a value of 1342 °C, at the end of simulation, as shown in Figure 4(d).

10. EFFECT OF ELECTRODE FORCE AND ELECTRICAL CURRENT ON NUGGET SIZE

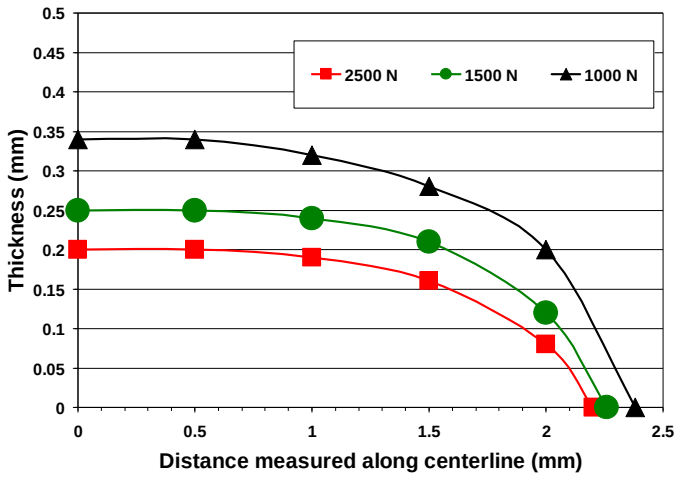


Figure 8: Effect of Electrode Force on the Size of Formed Nugget

In accordance with this Joule' heating impact, when contact region expanded, the generated heat at ports reduced and nugget size diminished, as shown in Figure 8. It must be noticed that the choice of force is crucial to get proper nugget. Heat generation because of electric present found to be considerable than time or force. Figure 9 shows nugget size for welding currents. For present 6.5 kA, the shaped nugget size was quite tiny. Growth of present to 7.5 kA dimensions of nugget is unusual.

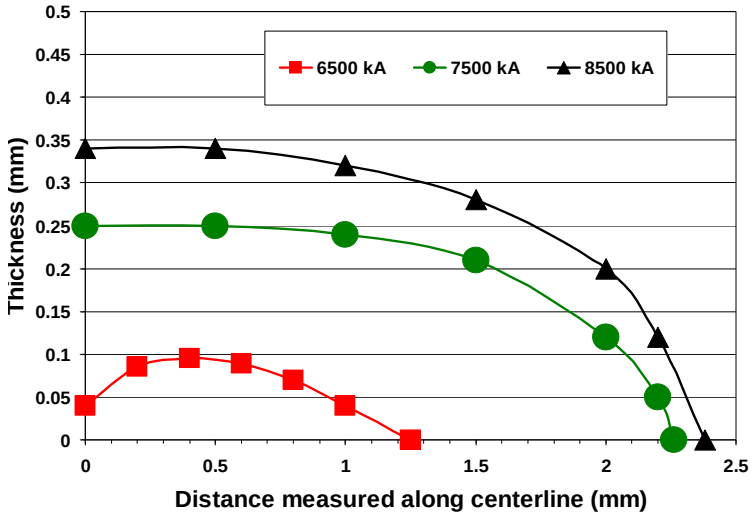


Figure 9: Effect of Electrical Current on the Size of Formed Nugget

11. ADVANTAGE OF MODELING AND SIMULATION OF SPOT WELDING PROCESS

After widely used of resistance spot welding process, most of the industries spent more cost on testing of weld joints through using tensile test for fracturing joints and examining quality of welded parts. Employing tensile testing to check the quality of the weld, the weld power causes the outer borders of this nugget to rip and then turn an erroneous measurement of the weld nugget diameter generated (Cheikh, Guendouze, 1995) and (Daniels, H. P. C., 1995) Ref no [6,7]. Therefore, finite element method is the key for providing perfect model of weld to allow for predicting nugget area through the developed isothermal, as shown in Figure 6. Size and strength of nugget can be successfully estimated and predicted without return back to make any experimental test. Saving information in simulation model can help the welder experts and engineer to create welding schedules for investigation of nugget formation, for different materials to be weld.

12. CONCLUSIONS

From the work carried out on design and simulation of 2D mathematical model of resistance spot welding, and analysis of the coupled thermal-electric-mechanical due to temperature variation and electrode effect to predict weld nugget formation and weld size as discussed, the following conclusions are arrived at.

- Using finite element version, a thermal-electric-mechanical using element model was created to describe the place welding procedure.
- The thermal-electric contacts have been modelled with contact resistance as a function of temperature.
- The benefit from weld model is to analyze both the squeeze and weld cycle, which the extracted results show that the stress distribution (Von-Mises Stresses) varies from the centre line, and passed towards the edge of the electrode and sheets.

- The methodology adopted in this work can be used while selecting parameters for a new product or part geometry that is to be welded, using electric resistance spot welding.
- With continuous period and growth of pressure, the nugget size decreases, as the contact region between sheets expanded. This leads to decrease in density and after that result in heat creation.
- It had been reasoned that the current chiefly affects the speed of nugget expansion, which at high current and low electrode forces, formed fusion area in large.
- Modelling of the spot welding cycle, based on the available previous works was also looked at, which led to reduction in the cost of testing weld quality, and enhancement facilitates of the development of various welding schedules.

12. ACKNOWLEDGMENT

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